

At what cost pervasive? A social computing view of mobile computing systems

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With the advent of pervasive systems, computers are becoming a larger part of our social lives than ever before. Depending on the design of these systems, they may either promote or inhibit social relationships. We consider four kinds of social relationships: a relationship with the system, system-mediated collaborative relationships, relationships with a community, and interpersonal relationships among co-located persons. In laboratory studies, the design of pervasive computers is shown to affect responses to social partners. We propose a model of how pervasive systems can influence human behavior, social attributions, and interaction outcomes. We also discuss some implications for system design.

Imagine a future in which individuals use mobile computers to maintain constant contact with a vast information network that unites everyone into a single community. Is this future a utopia or a social abomination? Technophiles see this as a utopian future. Given the current technological age, this future may even be the inevitable evolution of society. This same future, however, also perfectly describes the abominable world of the Borg, from the science-fiction television series *Star Trek: The Next Generation*. In this series, the Borg obsessively assimilate new technology into their bodies and their society. The result is a robot-like collective group without individuality, emotion, or compassion. Many individuals fear that as life becomes more technological it also becomes less "human."

Perspectives

Information technologies are taking on a large role in human social lives. Computers used to be tools that specialists employed to accomplish specific tasks. The revolutions in personal computing and communication networks, however, have broadened the application of information technology. Individuals now use computers to communicate with others and to work on a variety of tasks. Computing is no longer the domain of a few specialists. With the advent of pervasive computing, computers are leaving the largely sedentary and solitary desktop environment and are entering into human social lives in an unprecedented manner. We think of pervasive computing as a move from an interaction between an individual and a single device to an abundance of networked mobile and embedded computing devices that individuals and groups use across a variety of tasks and places. Important market trends in collaborative applications, mobile devices, and knowledge management reflect this change.

According to an International Data Corporation (IDC) report, the collaborative applications market is expected to reach \$2.1 billion in 1999, growing 19

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percent from 1998.¹ This explosion of collaborative applications will change the way users compute. By lowering the barriers to communication, these applications support interaction among workers, between companies, between companies and consumers, and among consumers.

The market research firm Frost and Sullivan projects the mobile computing market to reach \$99.9 billion by 2003.² This market includes a growing variety of laptop computers, hand-held computers, personal digital assistants (PDAs), wearable devices, and appliances. The IDC reports that portable-PC-unit sales alone are already 22 percent of desktop-PC-unit sales (15.5 million vs 71.5 million worldwide in 1998) and that over the next four years the unit-sales growth rate for portable units will be higher than that for desktop units. The rise of these portable computers means that computers are becoming more pervasive and will be affecting human lives in unforeseen ways.

Projections in an IBM study indicate that the knowledge-management market has reached tens of billions of dollars per year with a compound annual growth rate of 36 percent until 2003.³ The potential for these applications to allow workers to share information is tremendous. Creating a knowledge-sharing community, however, is a social challenge as much as a technological one. According to IBM strategist Alan Marwick, "Above all, it has become clear that the culture within an organization had to change. While the underlying technology of finding and distributing knowledge is necessary, it is not in itself sufficient."³ Overall these trends suggest that the success of emerging information technology will depend on how the technology affects human social behaviors.

We use the term "social computing" to refer to the interplay between persons' social behaviors and their interactions with computing technologies. Social computing involves both science and technology. As a domain of science, we seek to describe the relationships among social behaviors and machines so that we can reduce our uncertainty about how humans and machines will interact. As a domain of technology, we seek to apply social and behavioral science to the design of information technology systems that enable efficient collaboration and support natural social behaviors.

Social computing draws upon and extends previous research on social interfaces, computer-supported cooperative work (CSCW) systems, communities, and

interpersonal psychology. Researchers in these four areas study social behaviors. Social interface researchers study human social responses toward technology. CSCW researchers study social behaviors in computer-mediated communication (CMC). Community researchers study community influences on behavior. Interpersonal researchers study social behaviors in face-to-face interactions, and, in some cases, these researchers have studied the effect technologies have on these behaviors. The social impact of pervasive computing can be considered within each of these four perspectives.

Social interface theory

Humans sometimes respond socially to artifacts. Artifacts may be intentionally designed to encourage social responses, but more often they affect persons socially in ways unimagined by their creators. Researchers have found, for example, that individuals expect machines with female voices, in contrast to computers with male voices, to give better advice on love and worse advice on technology.⁴ Individuals perceive a machine's evaluation of its own performance to be more biased than its evaluation of another machine.⁵ Individuals even perceive machines as having personalities, and they like machines with personalities that are similar to their own more than they like machines with dissimilar personalities.^{6,7}

Social interface theory is built on the results of various studies demonstrating that humans respond socially in their interactions with machines.⁷⁻⁹ Humans are inclined to treat everything as social and natural. Therefore, they automatically and subconsciously use, whenever possible, what they know about their natural and social experiences to help them with their technological experiences. Carroll¹⁰ describes an experiment in which simulated intelligent help was given to users. Although the users praised the help system for assisting them in certain situations, in other situations the users blamed the system for their problems and attributed social traits to the system such as "fussy" and "distrustful."

Certain features of artifacts (such as when artifacts use natural language, fulfill a social role, or engage in contingent behavior) are especially likely to encourage social responses. Although some researchers (e.g., Reeves and Nass⁸) have made the strong claim that humans respond to machines as social actors, others (e.g., Kiesler and Sproull⁹) posit that humans can have social responses in interactions with machines (and in other situations) even though the

target of their responses is itself in no way social. Regardless of the mechanism behind human social responses to machines, researchers have proposed social interfaces as a way of using these responses to help make human-computer interaction natural, enjoyable, and efficient.

The extent to which pervasive computers will employ social interfaces remains an open question. Anthropomorphic software agents have been proposed as a potential user interface to an array of pervasive devices. Critics of anthropomorphic agents (e.g., Don, Brennan, Laurel, and Shneiderman,¹¹ Lanier,¹² and Shneiderman¹³) have argued that they are unnecessarily inefficient. Proponents, however, have found that anthropomorphic agents make interactions with a computer more enjoyable and have no negative side effects (van Mulken, Andre, and Muller¹⁴). Companies with commercial offerings in this space include iNAGO Incorporated (<http://www.inago.com/>), NetSage Corporation (<http://www.netsage.com>), Toggle Entertainment Inc. (<http://www.togglethis.com>), 7th-Street.com (<http://www.7thstreet.com>), Zoo Software Solutions (<http://www.zoosoft.co.uk>), ThingWorld.com (<http://www.thingworld.com>), 3D Planet, Inc. (<http://www.3dplanet.com/devzone.htm>), and Microsoft Corporation (<http://www.microsoft.com/>).

Even without explicitly anthropomorphic agents, however, many possible features of pervasive computers would seem to encourage social responses. For example, speech-based user interfaces have been proposed as an alternative to standard keyboards because speech is a natural form of communication, uses little physical space, and offers high mobility. Pervasive computers will often fulfill certain social roles for people, acting as assistants, delegates, or guides. Pervasive computers might appear to have a considerable level of intelligence and to know something about the relationships among persons, places, and events. In addition, the devices themselves will take on a personal nature by virtue of their extreme physical proximity. As computing becomes pervasive, encounters with artificial social actors may become common.

It is unclear what the consequences are of a proliferation of artificial social actors. Artificial social actors may be a natural and enjoyable way to interact with the new computers that suddenly will be everywhere. Alternatively, pervasive social interactions may be too much; individuals already are faced with the problem of being bombarded by too much information, and a new load of social information may

be unnecessarily burdensome. Like raw data, social interactions *per se* are not always useful or appropriate. A voice that is pleasant on a desktop machine may seem cloying and affected coming from a piece of clothing. Designers have a new challenge: to create successful personalities for the intimate devices that will live in people's cars, meeting rooms, shirt pockets, and, sometimes, even in their laps.

Mediated social interactions

Pervasive computers change our relationship not only with devices but with other individuals as well. Increasingly, information technologies are becoming communication systems. Communication appli-

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cations include e-mail, chat systems, multiuser domains (MUDs), discussion groups, videoconferencing, distance learning, real-time shared document editing, and other computer-supported cooperative work (CSCW) systems. For all these applications, some social interaction between people is mediated by a computer system. To gain an understanding of some of the work that has been done in CSCW, Greif¹⁵ put together a collection of readings.

Though the concept of groupware has been around for almost two decades, technologists are frustrated by its lack of commercial success. Grudin¹⁶ has addressed this failing by describing eight challenges that he believes must be met for groupware to be successful. At best, researchers have declared a partial victory with some systems. The Electronic Meeting System (EMS), for example, has been shown to improve some group processes and outcomes, but overall its success is limited.¹⁷

Some researchers (e.g., Grudin¹⁶ and Jones and Marsh¹⁸) have pointed out social factors that may influence the success of computer-mediated communication. One study has indicated that social communication is a stronger impetus for Internet use

than are information and entertainment applications.¹⁹ Similarly, the disruption of social behaviors may be a deterrent for using CSCW systems. As an example, videoconferencing systems are used relatively rarely. One possible reason is that bandwidth restrictions on video images typically give participants an awkward appearance. The resulting social discomfort often causes viewers to dislike videoconferencing. Researchers at BT Laboratories are studying how to incorporate social cues such as direction of gaze and spatial proximity into videoconferencing through virtual conferencing.²⁰

Even though the groupware market has disappointed expectations, the social impact of computer-mediated communication is already widespread. Many current Web applications include groupware functionality. Companies with CSCW Web applications include Adaptivity, Inc., Appoint.Net Inc., Change-point Corporation, Crosswind Technologies, Inc., Dataferret, FileNET Corporation, Instinctive Technology, Inc., IntegrationWare Inc., Jintek, Lotus Development Corporation, Microsoft Corporation, Pacifica Software, PlaceWare, Inc., PlanetAll.com, Inc., Russell Information Sciences, Inc., SevenMountains Software, Inc., Upshot Corporation, WebMan Technologies, Inc., and When Inc.

Traditional CSCW interactions have depended on desktop systems or other low-mobility devices. Pervasive computing promises to change that, however. Mobile information-processing devices and mobile communication devices are merging to allow new ways for individuals to communicate practically anywhere. Mobile telephones have built-in electronic address books; hand-held personal digital assistants (PDAs) have infrared connections; and alphanumeric pagers have support for reading e-mail. The potential exists for completely new kinds of pervasive computer-supported cooperative work systems.

The success of pervasive CSCW, like all CSCW, will depend largely on how the systems handle the social nature of human cooperation. Consider these examples. Pervasive systems could allow people to be reached at any time and anywhere, but individuals also need ways to avoid interruptions without seeming rude. The systems could make available useful personal information, including a person's present location, but individuals need ways to give out such information only to trusted recipients. Methods of negotiating the transfer of information from one system to another are now being developed. These negotiators include those used for electronic com-

merce Web applications, such as Kasbah (<http://ecommerce.media.mit.edu/Kasbah/>), AuctionBot (<http://auction.eecs.umich.edu/>), and Tete-a-Tete (<http://ecommerce.media.mit.edu/tete-a-tete>). An example of an on-line privacy agent specifically designed for negotiating personal information is described by Meyer.²¹ The answers to social concerns such as these will determine whether pervasive CSCW systems can reach their potential.

Communities

From newsgroups to MUDs to chat rooms, communities have formed through the networked medium. As computing becomes more pervasive it touches the lives of new communities. Computer companies have begun to explore the effect of communities on the computer market. As different groups of individuals are considered as the target market, these groups will drive new ways of computing to fit their needs and wants. One current market focus is women. Consider the following:

American women are the second largest economy in the world, with purchasing power 25 percent greater than the entire Japanese economy. US women-owned businesses generate about \$2.4 trillion in sales; nearly the same as the German economy. Yet few businesses have recognized the profit potential of this market or know how to properly serve it. CEO Arthur Martinez was able to turn Sears, Roebuck and Co. around by focusing on women, who serve as *de facto* purchasing agents for their homes; not just apparel and home fashions, but also electronics, tools, and auto parts (Shea²²).

A survey by the Pew Research Center for the People and the Press²³ found women have overtaken men among newcomers to the Internet. Of people who said they began using the Internet within the previous year, 52 percent were women and 48 percent were men.

Some companies have explored designing pervasive products for women and other groups. Philips Electronics N.V., for example, described their user-centered process for designing a product that would induce sensual feeling. Their target group was women between the ages of 18 and 30 and their target product was a pager. The design of these pagers was informed by interviews of their target group. Unlike the pagers that were common at the time, the new

designs could be worn as jewelry and had a very sleek, aesthetically pleasing case.²⁴

To appeal to a target group, developers often need to create an experience of community around a product. For some groups, computers as such are simply not a part of the community. At a fundamental level, humans think about social groups in terms of “us” vs “them,” or the groups that “I am in” (in-groups) and those that “I am not in” (out-groups).²⁵ Members and markers of an in-group are often favored and those of an out-group are often disparaged. Individuals may resist adopting a technology if it is associated with an out-group, and the technology itself may be a powerful marker in identifying group membership. Developers recently have begun to explore ways of creating community. One company, for example, advocates the use of a Web application that offers personal classified advertisements on an intranet in order to build a sense of community among employees.²⁶ As computing becomes pervasive, new applications to build community will become possible.

Interpersonal effects

In addition to being the object or the channel of a social interaction, pervasive computers can also have an indirect social effect. The presence of pervasive computers can influence interpersonal interactions, specifically synchronous face-to-face interactions between individuals.

In his review of technology’s impact on interpersonal interaction, psychiatrist Edward Hallowell²⁷ argued that individuals are suffering from a lack of authentic psychological encounters or “human moments.” Evidence includes research at Carnegie Mellon University that suggests that Internet use of as little as four hours per week is associated with higher levels of depression and loneliness. Face-to-face interaction, on the other hand, reduces the levels of hormones involved in stress, fear, and worry and increases the levels of hormones involved in trust, bonding, attention, and pleasure. Moreover, Hallowell argues that these face-to-face interactions can result in authentic psychological encounters only if technology is not part of the interaction. “To make the human moment work, you have to set aside what you’re doing, disengage from your laptop, abandon your daydream, and focus on the person you’re with” (page 60). Human moments require physical presence and emotional and intellectual attention.

Information technologies can interfere with positive social encounters in many ways. Computers have been designed primarily as devices to be used by a solitary person. Personal computers (PCs), for example, are truly personal in the sense that they typically support the work of an individual only. This becomes apparent whenever two persons try to work together with a single computer. Typical obstacles include (1) difficulties sharing the keyboard and pointing device, (2) difficulties attending to both the screen and the collaborator, and (3) difficulties the nonuser has in distinguishing the user’s navigation behaviors, such as scrolling or paging down.

It can be awkward to use a computer with someone, and it also can be awkward to use a computer around someone. As an example, persons often avoid using laptop computers in meetings or other social situations. Using computers is typically a sufficiently complex task that it distracts a person’s attention away from others. Moreover, the sound of typing and the raised screens of laptops themselves can be disruptive in meetings. End users who are engaged in customer contact, such as salespersons, avoid using computers because they cannot afford to impair the quality of their social interactions.

Independent of how the devices are used, computers themselves can make an antisocial statement. In many persons’ minds, computers are associated with a lack of social engagement. Those seen using computers may be labeled with social stereotypes, like “geek.” The common, “one-size-fits-all,” industrial appearance of computers is at odds with the personal, fashionable nature of the possessions with which people like to be seen. Being seen with a computer may not be socially desirable. Conversely, individuals may select devices to invoke a certain stereotype. They may use technology as a status symbol or fashion statement. Ultrasmall cellular phones, for example, can create a certain social impression. The impression a device makes, therefore, can be positive or negative, depending on the device and the social groups involved.

Many companies offer mobile computing devices, including 3Com Corporation, Casio Computer Company, Ltd., Hewlett-Packard Company, IBM, Philips Electronics, and Sony Corporation. These devices range from simple recording devices to complex versatile laptop computers. Most of the products in this category focus on workplace efficiency. Although some acknowledge their presence in a social context through styling, these devices are primarily meant

to be used by one person. Their interfaces do not take into account their possible use in the presence of individuals other than their owners. A few are starting to be created with interactions that border on social interactions, however. Some of these are the LoveGety** in Japan, and Tamaguchi** pets and other virtual pets. So far, however, these devices do not support both productivity and social interaction.

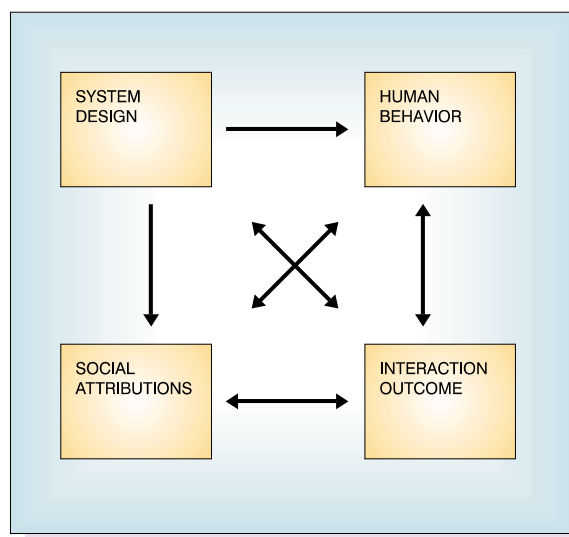
The present empirical investigations concern interpersonal effects rather than social interfaces, CSCW systems, and communities. Social interface research has established the importance of social behaviors in interactions between a person and a machine. CSCW research has focused on computer-mediated interactions between two or more persons. Community researchers have studied communities as markets for technology. In our research, we look at social behaviors that are directed toward a person rather than a machine, in the context of a collaboration that is face-to-face rather than computer-mediated within a community of experienced computer users.

Theoretical model

There are several possible mechanisms through which mobile devices can affect social relationships, ultimately affecting outcomes such as the productivity of collaborative work. Drawing on existing work in interpersonal psychology,²⁸ we propose that system designs can influence both human behaviors and social attributions, and that system designs, human behaviors, and social attributions together can affect interaction outcomes. Our theoretical model of the interrelationships among these components is represented in Figure 1. Although the focus here is on an interaction between one person who is using a computer and one who is not, with the user being the primary target of these mechanisms, the model applies equally well to both users and nonusers and to interactions between two users using the same or different devices.

For each of the four general components in our model, we propose some specific factors, as shown in Table 1. This listing of specific factors is not intended to be exhaustive; instead, these factors are the ones we have focused on in the present research. In addition, we have focused on the psychological impact of these factors. In some cases, factors could be assessed by either objective or subjective measures. As an example, "agreeableness" is a personality trait. This trait could be assessed by objectively

Figure 1 A model of social Impact



measuring some aspect of a person's behavior, such as the frequency with which that person went along with a partner's suggestion. Alternatively, the partner's perception of the trait could be assessed, independent of how the person actually behaved. In these studies, our focus is on the psychological impact that system design factors have on persons' social interactions, and we therefore have assessed persons' perceptions of these factors.

This model starts with device design. Some possible device factors include whether individuals believe that they could use the device easily, whether the device is or resembles a familiar device, whether users could share the input device and the display with non-users, and whether the device appears useful in the current context. Device design influences human behaviors, social attributions, and interaction outcomes.

Social attributions are judgments that a person makes about a partner's dispositions, traits, roles, and group memberships. Individuals have a tendency to make inadequate allowance for the effect that situations have on a partner's behavior and instead attribute behaviors to enduring individual characteristics.²⁹ As an example, consider a person using a head-mounted display (HMD). Using an HMD restricts the person's ability to make eye contact. Eye contact, however, is a social cue for extroversion in some cultures. It is possible that individuals who in-

Table 1 Specific social computing factors

System Design	Human Behavior	Social Attribution	Interaction Outcome
Accessibility Familiarity Input sharing Output sharing Relevance	Appeal Disruption Perceiver distraction Power User distraction	Agreeableness Extroversion Identification	Device satisfaction Productivity Social attraction

teract with a person using an HMD will inadequately account for the effect that the HMD has on the person's behavior and instead attribute the relative lack of eye contact to a personality characteristic such as introversion. The two personality dimensions that are fundamental to social interaction are agreeableness and extroversion. These two dimensions influence interpersonal interaction outcomes, such as persons' satisfaction with an interaction, their liking of their partner, and the successfulness of their interaction.^{7,30} Social attributions, therefore, include factors such as whether a person is agreeable or disagreeable, whether a person is extroverted or introverted, and whether a person is a member of an in-group or an out-group. Social attributions are reciprocally related to both human behaviors and interaction outcomes.

Human behaviors are the actions individuals take while interacting with the device, with other individuals, and with both the device and other individuals. Some possible factors include whether using the device makes the user appear awkward, whether using the device interferes with natural social behaviors, whether the device distracts nonusers from their social interaction, whether the device alters the distribution of interpersonal control between partners, and whether the device distracts users from their social interaction. Human behaviors reciprocally influence both social attributions and interaction outcomes.

Interaction outcomes are consequences of an interaction, including whether the interaction is successful and whether future similar interactions are desired. Interaction outcomes are the benefits of interacting. They involve both cognitive and affective evaluations of what happened and whether the intentions that motivated the interaction were realized. In work settings, interaction outcomes can be thought of as the quantity and quality of work produced in a social exchange. Both within and outside of work settings, social interactions affect relat-

edness, community, and goodwill. Some possible factors include whether the technology involved is positively evaluated, whether partners like interacting with each other, and whether the goals of the interaction are accomplished.

Although the model illustrates system design mainly as the cause of social effects, interaction outcomes over time can affect system designs. In particular, individuals will prefer to use systems that support positive interaction outcomes over those that do not. Designers of future systems can be guided by the successfulness of earlier designs.

Empirical investigations

We conducted two studies to explore some of these theoretical relationships empirically. In our first study, we examined subjects' schemata, or mental representations, of the relationships among system design, human behaviors, social attributions, and interaction outcome. In the second study, we investigated the effect of these schemata by manipulating system design factors experimentally and assessing their effect on social attributions, human behaviors, and interaction outcomes during a laboratory task.

Study 1. One way in which machines can affect human social lives is through the expectations individuals have about how machines and humans interact. Individuals may believe, for example, that technology generally moves humans away from social contact. People may have stereotypes about what computer users are like compared to nonusers. Moreover, different devices may be associated with different expectations. Psychologists use the term "schema" to refer to a collection of mental representations that are interassociated and function together as a unit. Schemata are constructed over time as the result of an individual's experiences. Although individuals may differ in terms of their schemata, the homogeneity of a particular culture can produce a

number of consensual schemata, such as shared stereotypes. Elements in a schema are thought to be linked together through their concurrence in experience. The experience of any particular element disposes a person to infer (consciously or otherwise) associated elements.^{31,32} In our theoretical model, we have proposed certain associations among various elements. It may be that elements in persons' mental representations are similarly linked, forming reliable schematic representations of computer users. If this is so, then these schemata would predictably predispose people to certain expectations, judgments, and inferences about computer users.

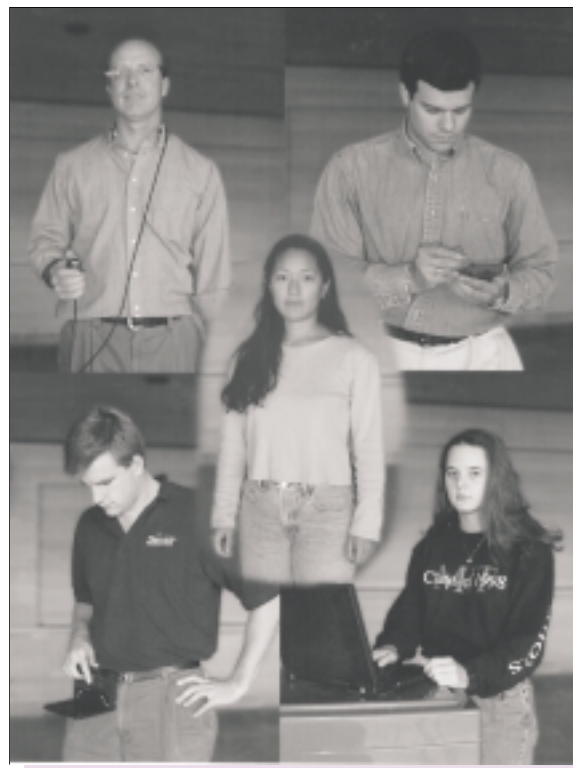
Schemata concerning computer users may have important consequences. The kind of device a person uses may impact how the person is perceived and how interactions with the person are remembered.³³ How a person is perceived can impact how a person behaves. Studies have shown³⁴ that a perceiver's expectations can alter that perceiver's behavior in ways that cause those expectations to be fulfilled. Importantly, these effects may occur even in the absence of any actual interaction with the person being judged; in a number of studies, participants have demonstrated reliable biases in social attributions based on photographs,³⁵ motion pictures,³⁶ or written descriptions.³⁷

In our first study, we examined the evidence for schemata concerning system designs, human behaviors, social attributions, and interaction outcomes. To isolate the effect of the schemata, we have followed the methodology of social psychologists and presented participants with photographs of persons (targets) with different devices. Through these photographs, we intended to access different schemata. We then measured participants' social attributions and their expectations about the devices, the targets' behaviors, and the outcome of an interaction with the target.

Method. A battery of five questionnaires designed to assess schemata concerning the social impact of technology was administered to 31 participants. Answers to all questionnaire items were in the form of six-point Likert scales,³⁸ with "1" labeled "disagree strongly" and "6" labeled "agree strongly."

The first questionnaire assessed general expectations about social life and technology. This questionnaire consisted of these four items: "I think computers help foster links among diverse people," "Overall, I think the social benefits of computers outweigh their so-

Figure 2 Sample social target stimuli



cial costs," "I think on-line relationships are weaker than real-life relationships," and "I think people who use computers have less social activity than those who do not." Participants then viewed images of five different targets. Four of these images depicted a target with a computing device. One image depicted a target without a device. These images are illustrated in Figure 2.

The second questionnaire assessed perceptions of the system designs. The variables and the items that assessed them were: accessibility—"I think I could use the computer reasonably well"; input sharing—"It would be easy for me to input information into the computer"; output sharing—"It would be easy for me to see the display of the computer"; and relevance—"The computer will be useful during our interaction."

The third questionnaire assessed expectations of human behaviors. The variables and the items that assessed them were: appeal—"The computer makes

the person look awkward”; disruption—“The computer will make the interaction less natural”; perceiver distraction—“The computer would distract me during our interaction”; power—“Because of the computer, the person would have an advantage over me”; and user distraction—“The computer would distract the person during our interaction.”

The fourth questionnaire assessed participants’ social attributions to these targets. We assessed the perceived personality of the target along the dimensions of agreeableness (agreeable to disagreeable) and extroversion (extroverted to introverted). The multi-item personality scales used in this study and in Study 2 are standard psychological instruments (for more information, see Dryer and Horowitz³⁰). We also assessed identification with the item “I am the sort of person who would use that kind of computer.”

The fifth questionnaire assessed participants’ expectations of the interaction outcome with a single item: “I would like interacting with this person.” Interaction outcome here is simply a general measure of social attraction.

The four computing devices represented were (1) a laptop—a mobile computer (IBM ThinkPad*), (2) a PDA—a hand-held personal digital assistant (3Com Palm III**), (3) a “wearable”—a belt-worn sub-notebook computer (custom-modified IBM PC110), and (4) an HMD—a computer with a head-mounted display (Kopin CyberDisplay) and a single-hand custom-made input device. The devices differed along many factors and were selected to represent a range of possible pervasive computing form factors, ranging from the relatively familiar to the less familiar. As we suggested with our theoretical model, less familiar technologies might seem more intrusive than more familiar ones. The sequence of devices therefore represents a five-level (four devices and one no-device image), within-subject independent variable that we called “device type.”

The targets presented were two women and three men. Each individual target was seen in only one image. In order to control for the possible influence that the targets’ appearance might have on participants’ judgments, half of the participants saw each target with one device, and the other half saw the same target with a different device. That is, two different questionnaires were prepared, with the order of the targets and the order of the devices randomized, with the restriction that no target could be paired with the same device in both conditions. We

treated these questionnaires as a two-level, between-subject independent variable that we called “questionnaire.”

We also hypothesized that participants’ social attributions might differ according to whether the target appeared to be attending to the device or to the viewer. To examine this, we photographed the targets looking at the device and looking at the viewer. Half of the participants saw all the targets looking away from the viewer (and at the device when possible) and the other half saw all the targets looking at the viewer. We treated this as a two-level, between-subject independent variable that we called “eye contact.”

In order to rule out the possibility that the schemata assessed existed only among persons who are relatively inexperienced with technology, our 31 participants were all selected from the IBM Research technical community. Their ages ranged from 19 to 67 with a mean age of 40. Nine of the participants were women.

Results and discussion. In our first study, we found evidence that individuals may access different schemata depending on the system designs they encounter.

General expectations. The first questionnaire revealed that the participants have ambivalent beliefs about the relationship between technology and social life. Most participants agreed with the statements “I think computers help foster links among diverse people” (93.6 percent) and “Overall, I think the social benefits of computers outweigh their social costs” (80.6 percent). Participants also tended to agree, however, with the statements “I think on-line relationships are weaker than real-life relationships” (90.3 percent) and “I think people who use computers have less social activity than those who don’t” (58.1 percent).

All other data from this study are summarized in Table 2.

Perceptions of system design. The second questionnaire revealed that participants’ perceptions of system design factors differed significantly as a function of device type. The mean responses on the system design variables are shown in Figure 3. These data were analyzed with four separate four-level (device type) repeated-measures analyses of variance. These analyses revealed that the devices differed significantly along all four system design variables: for

Table 2 Mean questionnaire responses

	No Device	Laptop	PDA	Wearable	HMD
Accessibility	n/a	4.93	4.21	3.52	3.14
Input sharing	n/a	3.62	3.10	2.62	2.24
Output sharing	n/a	3.59	3.03	2.76	2.21
Relevance	n/a	3.61	3.57	3.39	3.04
Appeal (lack of)	n/a	3.03	2.45	3.69	4.03
Disruption	n/a	3.62	3.34	4.34	4.76
Perceiver distraction	n/a	3.34	3.14	4.00	4.62
Power	n/a	3.28	3.24	2.83	3.34
User distraction	n/a	4.07	3.45	4.21	4.62
Agreeableness, eye contact	3.98	2.22	3.26	0.10	1.50
Agreeableness, no eye contact	0.61	2.90	3.05	3.01	3.11
Extroversion, eye contact	3.35	3.29	3.48	3.88	3.87
Extroversion, no eye contact	2.60	3.63	4.14	3.91	2.80
Identification, eye contact	n/a	4.13	4.20	2.47	2.27
Identification, no eye contact	n/a	4.92	4.92	3.69	2.77
Social attraction, eye contact	4.56	4.06	4.19	3.75	3.12
Social attraction, no eye contact	3.77	4.00	4.23	3.85	3.69

output sharing, $F(3, 26) = 7.79, p < .001$; for input sharing, $F(3, 26) = 7.62, p < .001$; for accessibility, $F(3, 26) = 15.99, p < .001$; for relevance, $F(3, 26) = 2.97, p < .05$. (The F statistic is the sample variance accounted for by one effect, tested over the variance, not accounted for by any other effect tested. The level of significance of this statistic is called the p value, which represents the probability that the result is due to chance. For a detailed explanation of statistical analysis, see Hildebrand.³⁹) The between-subject factors “questionnaire” and “eye contact” had no significant effects. To assess the relative importance of these factors, the data were reanalyzed with a single multivariate repeated-measures analysis of variance. The device factor was again significant for all four system design variables and for the multivariate effect; $F(12, 240) = 4.06, p < .001$ from the exact statistic.

Expectations of human behaviors. The third questionnaire revealed similar effects on the participants' expectations for the targets' behaviors. The mean responses on the human behavior variables are shown in Figure 4. These data were analyzed with five separate four-level (device type) repeated-measures analyses of variance. In addition, to test the relationship between these variables and device familiarity, a linear within-subject contrast was performed. These analyses revealed that the devices differed signifi-

cantly along four of the human behavior variables, and that they tended to differ in the order expected due to familiarity: for user distraction, $F(3, 26) = 7.21, p < .001$, the contrast $F(1, 28) = 6.44, p < .05$; for perceiver distraction, $F(3, 26) = 15.80, p < .001$, the contrast $F(1, 28) = 30.78, p < .001$; for appeal, $F(3, 26) = 12.28, p < .001$, the contrast $F(1, 28) = 13.76, p < .001$; for power, $F(3, 26) = 3.17, p < .05$, the contrast $F(1, 28) = .07, p$ not significant; and for disruption, $F(3, 26) = 13.29, p < .001$, the contrast $F(1, 28) = 33.30, p < .001$. The between-subject factors “questionnaire” and “eye contact” had no significant effects. To assess the relative importance of these factors, the data were reanalyzed with a single multivariate repeated-measures analysis of variance. The device factor was again significant for all human behavior variables except power and for the multivariate effect: $F(15, 246) = 4.01, p < .001$, calculated from Pillai's Trace.⁴⁰

Social attributions. The fourth questionnaire revealed that participants' social attributions differed as a function of device type. As shown in Figure 5, targets with familiar devices (or no device) are perceived to be more socially desirable than those with less familiar devices. These data were analyzed with three separate repeated-measures analyses of variance. Like the previous analyses, the within-subject vari-

Figure 3 System design: Mean perceptions by device type

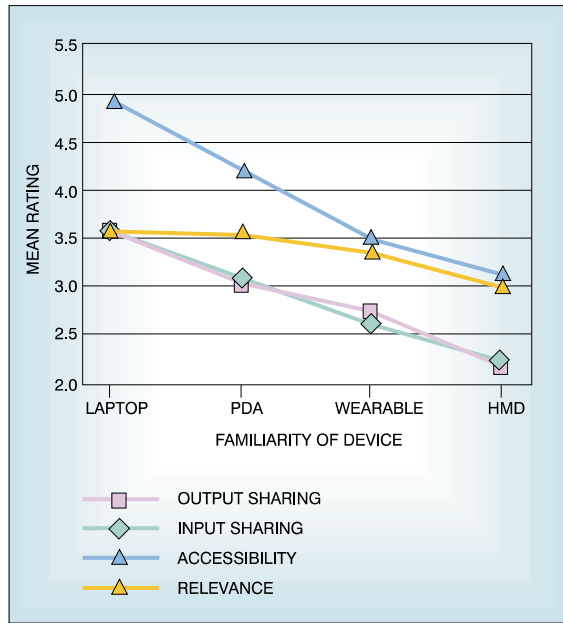


Figure 5 Social attributions: Mean attributions by device type when target is making eye contact

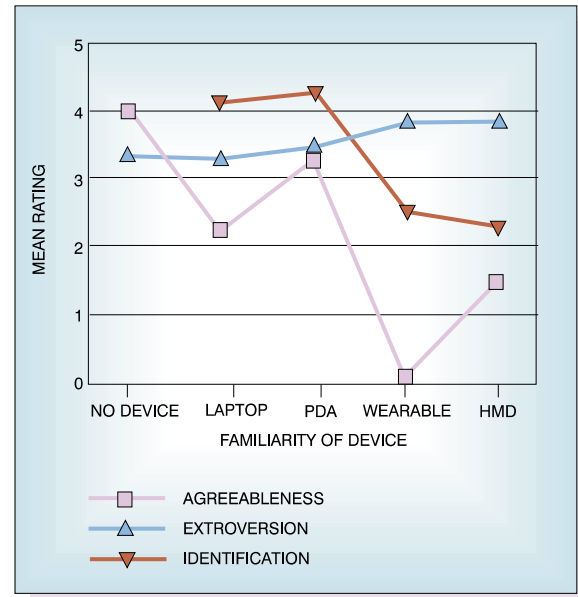
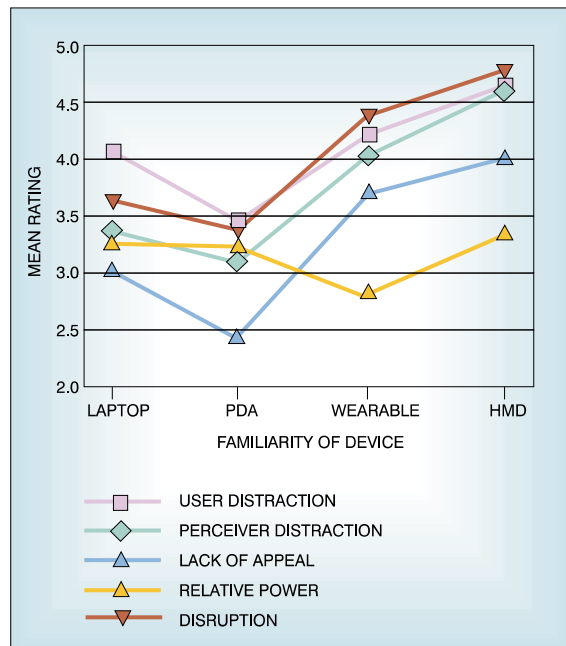


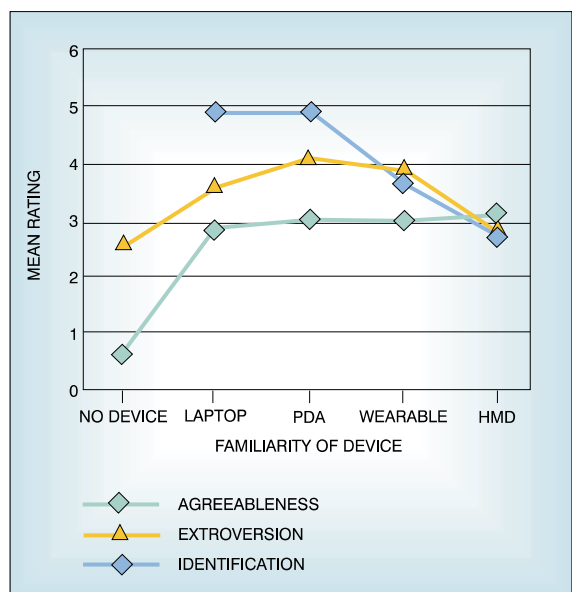
Figure 4 Human behavior: Mean expectations by device type



able (device type) had four levels for the dependent measure “identification.” For the dependent measures “agreeableness” and “extroversion,” however, the within-subject variable had five levels, which include the no-device targets as well as the laptop, PDA, wearable, and HMD targets. Differences were found for the between-subject factor “eye contact” but not for “questionnaire.” For the agreeableness analysis, the only significant effect is for the interaction between agreeableness and eye contact: $F(4, 108) = 6.06, p < .001$. The linear contrast for this effect is also significant: $F(1, 27) = 15.48, p < .001$.

Targets with no devices or familiar devices are perceived as more agreeable than those with unfamiliar devices, but only when they are looking at the perceiver. For the extroversion analysis, none of the effects are statistically significant. For the identification analysis, the main effects for device and for eye contact are both statistically significant: for device, $F(3, 78) = 23.39, p < .001$; for eye contact, $F(1, 26) = 8.14, p < .01$. The linear contrast for the device effect is also statistically significant: $F(1, 26) = 34.88, p < .001$. In general, participants tended to identify more with targets using familiar devices than they did targets using unfamiliar devices, independent of whether the target was pictured at-

Figure 6 Social attributions: Mean attributions by device type when target is not making eye contact



tending to the device. Participants also seemed to identify with targets who were attending to the device more than they did those who did not. To assess the relative importance of these factors, the data were reanalyzed with a single four-level multivariate repeated-measures analysis of variance. In this analysis, the device factor was significant only for the identification measure and for the multivariate effect: $F(9, 243) = 5.68, p < .001$, calculated from Pillai's Trace.

As shown in Figure 6, the effect of technology generally is less clear when the target is not making eye contact. Targets with no device were perceived as having socially undesirable personalities when they were not looking at the viewer. This could be because the participants had an easy explanation for why the other targets were not looking at the viewer; those targets were engaged with a device. When the target looked away and did not have a device, the participants had no easy explanation for the lack of eye contact except that the target was antisocial. This demonstrates the importance that behaviors such as eye contact can have on social attributions.

Expectations of interaction outcome. The fifth questionnaire assessed social attraction toward the tar-

Figure 7 Interaction outcome: Mean expected social attraction by device type when target is making eye contact

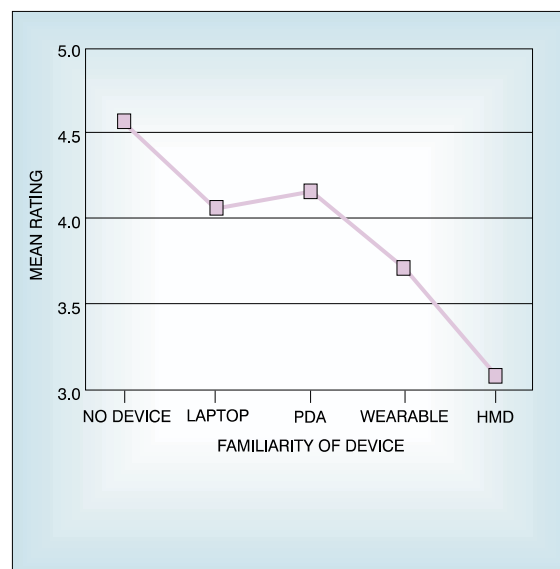
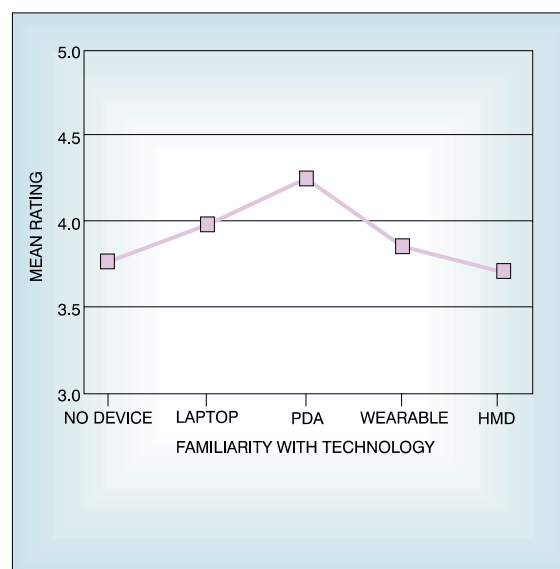


Figure 8 Interaction outcome: Mean expected social attraction by device type when target is not making eye contact



gets. As shown in Figure 7, expectations for the interaction outcome differed as a function of device

Table 3 Interrelationships among variables

	Accessibility	Input Sharing	Output Sharing	Relevance	Appeal	Disruption	Perceiver Distraction	Power	User Distraction
Accessibility	n/a								
Input sharing	.372bcd**	n/a							
Output sharing	.244bcd**	.541bcd**	n/a						
Relevance	.098bcd	.062bcd	-.071bcd	n/a					
Appeal	.050cd	.175cd	.090cd	-.053cd	n/a				
Disruption	-.034cd	.021cd	-.026cd	.174cd	.391acd**	n/a			
Perceiver distraction	-.117cd	-.055cd	-.060cd	.069cd	.362acd**	.627acd**	n/a		
Power	-.294cd**	-.045cd	.070cd	.110cd	-.293acd**	-.023acd	.008acd	n/a	
User distraction	-.117cd	-.055cd	-.060cd	.069cd	.142acd	.341acd**	.577acd**	.182acd	n/a
Agreeableness	.046bd	-.097bd	-.092bd	0.87bd	.093ad	-.172ad	-.130ad	-.167ad	-.156ad
Extroversion	-.107bd	.125bd	.184bd*	.024bd	-.112ad	-.062ad	-.132ad	.085ad	.081ad
Identification	.621bd**	.310bd**	.294bd**	.318bd**	-.245ad**	-.211ad*	-.181ad	.081ad	-.185ad*
Social attraction	-.022bc	.088bc	.026bc	.104bc	-.189ac*	-.088ac	-.002ac	-.024ac	-.047ac

a Controlling for system design variables: accessibility, input sharing, output sharing, and relevance

b Controlling for human behavior variables: appeal, disruption, perceiver distraction, relative power, and user distraction

c Controlling for social attribution variables: agreeableness, extroversion, and identification

d Controlling for the interaction outcome variable, social attraction

* $p < .05$ two-tailed

** $p < .01$ two-tailed

type. These data were analyzed with a repeated-measures analysis of variance with familiarity of device as a within-subject factor and eye contact as a between-subject factor. Both factors were statistically significant: for the within-subject factor, $F(4, 108) = 3.53, p < .01$; and for the between-subjects factor, $F(1, 27) = 1100.87, p < .001$. The interaction between the two factors and the effect of the questionnaire factor were not significant. As shown in the figure, the progression of mean attraction when the target looked at the viewer is nearly monotonic; in general, the less familiar the technology, the less attractive its user. A linear contrast of the means for the device factor was significant: $F(1, 27) = 12.24, p < .01$.

There may be exceptions to the effect of familiarity. Targets using the laptop computer were perceived as less socially attractive than might be expected for such a familiar technology. A similar pattern is evident in the agreeableness ratings and across the human behavior ratings. It is possible that the participants have had negative experiences with laptops in social settings, and that these experiences have led to somewhat negative expectations. As with the social attributions, the effect of technology on social attraction changes when the target does not make eye contact. As shown in Figure 8, the familiarity of the device has little effect on social attraction. With no apparent reason for looking away, targets with-

out a device become less attractive social partners than those making eye contact.

Interrelationships among elements. In our theoretical model, we predicted interrelationships among the system design, human behavior, and interaction outcome variables. To investigate the actual mental associations among these elements, we calculated the partial correlation coefficients of the variables assessed in each pair of our model's four components, controlling for the variables in the other pair. These coefficients are presented in Table 3.

Among the system design and human behavior variables, the relationship between accessibility and power is statistically significant: partial correlation coefficient = $-.294, p < .01$. When participants believed that a particular device would be easy for them to use, they also expected that a person using the device would not have an advantage over them in an interaction. No other relationships between system design and human behavior variables were statistically significant.

Several relationships are statistically significant among system design and social attribution variables: for output sharing and extroversion, the partial correlation coefficient = $.184, p < .05$; for accessibility and identification, the partial correlation coefficient = $.621, p < .01$; for input sharing and iden-

Agreeable- ness	Extro- version	Identifi- cation	Social Attraction
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			Accessibility
			Input sharing
			Output sharing
			Relevance
			Appeal
			Disruption
			Perceiver
			distraction
			Power
			User distraction
n/a			Agreeableness
-.175abd	n/a		Extroversion
.111abd	-.145abd	n/a	Identification
.433ab**	.265ab**	.187ab*	Social attraction

tification, the partial correlation coefficient = .310, $p < .01$; for output sharing and identification, the partial correlation coefficient = .294, $p < .01$; and for relevance and identification, the partial correlation coefficient = .318, $p < .01$. When participants saw a target using a device with a seemingly easy-to-share display, they perceived the target as relatively outgoing. Similarly, participants saw themselves as persons who would use the device when the device was perceived to be easy to use, easy to enter information into, easy to see its display, and useful during a social interaction. No other relationships were statistically significant.

Among the human behavior and social attribution variables, the participants' expectations for a target's behavior were associated with their attributions of the target's group membership. The statistically significant relationships were: for appeal and identification, the partial correlation coefficient = $-.245$, $p < .01$; for disruption and identification, the partial correlation coefficient = $-.211$, $p < .05$; and for user distraction and identification, the partial correlation coefficient = $-.185$, $p < .05$. When participants expected the target's use of a device would make the target look awkward, disrupt the natural flow of the interaction, or distract the target, the participants saw themselves as persons who would not use that device. No other relationships were statistically significant.

Among the relationships between human behavior variables and interaction outcome, appeal is significantly related to social attraction: the partial correlation coefficient = $-.189$, $p < .05$. When par-

ticipants expected the target's use of a device would make the target look awkward, the participants also tended to expect that they would not like interacting with the target. No other relationships were statistically significant.

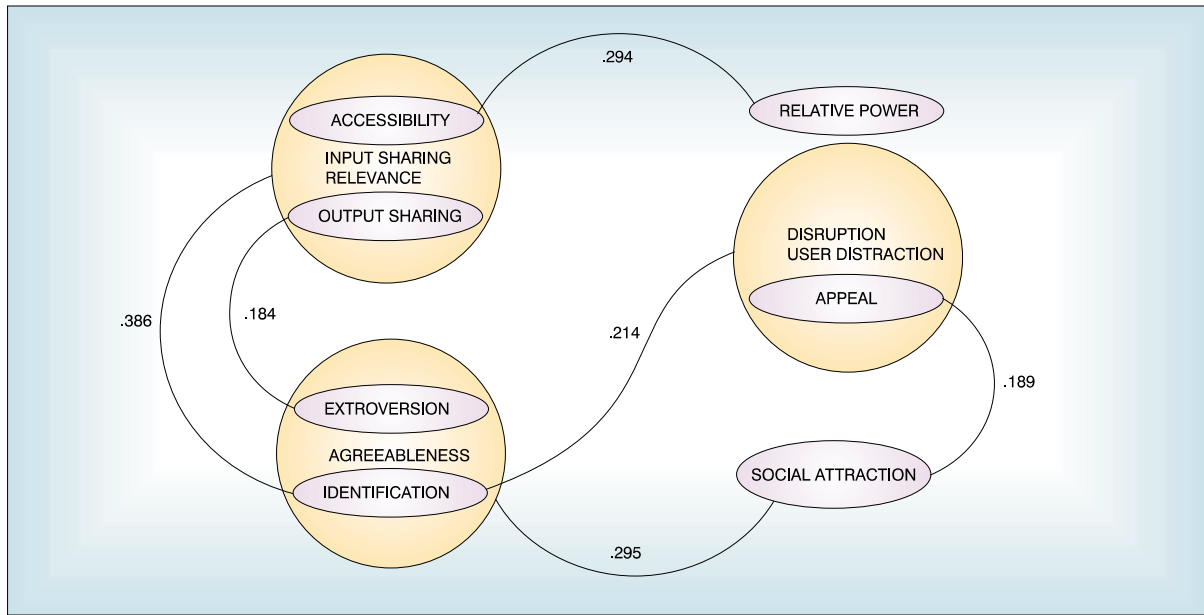
All of the social attribution variables are significantly related to interaction outcome: for agreeableness and social attraction, the partial correlation coefficient = .433, $p < .01$; for extroversion and social attraction, the partial correlation coefficient = .265, $p < .01$; and for identification and social attraction, the partial correlation coefficient = .187, $p < .05$. Participants tended to expect that they would like interacting with a target when they perceived the target to be agreeable or extroverted, and when they saw themselves as persons who would use a device like the target's. In our sample, in-group members and partners with agreeable and extroverted personalities are more socially desirable than out-group members and partners with disagreeable and introverted personalities.

Among system design variables and interaction outcome, no relationships are statistically significant. The system design variables appear not to be directly related to social attraction.

The statistically significant partial correlation coefficients are summarized in Figure 9. In cases where a variable is significantly related to multiple variables in a single component, the average partial correlation coefficient is presented. These findings can be summarized by highlighting a few key relationships:

1. The accessibility of a device, or the degree to which it appeared to be easy for participants to use, is related to the power that is expected between the participant and the target. If participants feel that a target can use a device better than they could, they also tend to feel that the target will have an advantage over them.
2. Output sharing and extroversion are related. Targets using devices with apparently easy-to-share displays tended to be seen as more extroverted. Extroversion along with the other social attributions of agreeableness and identification are associated with expectations of an enjoyable interaction.
3. Appeal is associated with social attraction. When participants expect that a device will make the target look awkward, they tend to expect that the interaction will be less enjoyable.

Figure 9 Interrelationships among variables



4. All the system design variables and most of the human behavior variables are associated with identification. When participants have negative expectations about a device or its effect on a partner's behavior, they tend to see themselves as persons who would not use that device. This makes the target an out-group member, which in turn is negatively associated with participants expecting that they would like interacting with the target. In general, the participants tended not to associate the system design elements directly with the interaction outcome elements. Instead, the system design elements appear to be mentally interassociated with the human behavior and social attribution elements, and these latter elements are in turn associated with the expected interaction outcome.

Study 2

Our first study indicated that different devices can reliably trigger certain schematic responses. Relative to not using a computer, the use of a computer in a social setting is associated with a negative stereotype, and the less familiar the technology, the more negative the stereotype.

Given these results, we wondered whether these stereotypes might have a lasting effect. We could imagine that the stereotypes are sufficiently weak that they would have no significant effect on actual interactions. In interpersonal interactions, individuals have direct evidence about how a computer system is designed, how a partner behaves, what social attributions are appropriate, and how the interaction turns out. This evidence might overwhelm prejudices induced by their schemata. In our second study, therefore, we assessed how technology might affect actual social interactions.

Method. We invited 17 pairs of participants into our laboratory to participate in a study of "collaborative problem solving." Like participants in Study 1, our participants were all recruited from the IBM Research technical community. Their task, as a team, was to solve a series of problems. They were informed that an optimal solution to the problem does exist⁴¹ and that any team that produced the optimal solution would receive a \$100 bonus. (None did.) In each case, one participant was assigned a computing device. The main role of the computing device was, ostensibly, to collect data for the experimenter. The device was used to present the tasks and to record the solutions

Figure 10 An illustration of the four conditions



generated by each pair. The tasks were designed so that, although the teams had to use the device, the device did not help the teams solve the problems. The laboratory sessions were videotaped.

The two system design factors manipulated were familiarity and output sharing. Participants received one of two different devices, either a relatively familiar device (IBM ThinkPad laptop computer) or a relatively unfamiliar device (an IBM PC110 hand-held computer). The interaction was manipulated so that it was either relatively easy or difficult for the non-user to see the display of the device. Specifically, for the laptop computer, participants were either seated together on one side of a small table or across from each other on opposite sides of the table. For the hand-held computer, the user received either a standard hand-held device or a custom-made belt-worn device designed so that the display could be seen only if the partners stood side by side. These factors are

illustrated in Figure 10. Although the devices differed in other ways than familiarity and output sharing, they were selected as devices through which we could manipulate both those variables and also run exactly the same software program in all four conditions.

The participants' social attributions, their interpersonal behaviors, and the outcome of the interaction were assessed with questionnaire measures before, during, and after the problem-solving interaction. These measures were designed to assess (1) perceived agreeableness and extroversion, (2) disruption of output sharing, (3) perceived power, (4) device satisfaction, (5) perceived productivity, and (6) social attraction. Perceived agreeableness and extroversion were assessed using the same standard measures used in Study 1. Disruption was coded, from the videotapes of the interaction, by a trained rater who was blind to the experimental hypothesis. Pairs

Table 4 Mean ratings across time by device familiarity and display type

	Familiar			Unfamiliar			Easy to share			Hard to share		
	Before	During	After	Before	During	After	Before	During	After	Before	During	After
NONUSER												
Agreeableness	3.18	4.14	4.36	3.22	3.79	3.01	2.81	4.29	4.17	3.59	3.65	3.20
Extroversion	3.24	2.52	2.59	4.04	3.46	1.72	3.83	2.52	1.98	3.44	2.54	2.21
Relative power	2.96	1.83	1.71	3.38	1.88	2.12	3.46	1.96	1.96	2.88	1.75	1.88
Device satisfaction	2.67	1.82	1.82	2.83	1.50	2.12	2.83	1.94	2.21	2.67	1.38	1.83
Perceived productivity	3.62	3.76	3.95	3.66	3.81	3.88	3.74	3.85	3.98	3.53	3.72	3.84
Social attraction	3.67	3.61	3.57	3.83	3.71	3.29	3.83	3.74	3.74	3.67	3.58	3.12
USER												
Agreeableness	3.52	3.81	3.98	3.00	3.25	3.56	2.96	3.50	3.73	3.56	3.56	3.81
Extroversion	3.62	5.21	4.21	1.38	2.12	1.00	2.88	4.88	5.13	2.13	2.46	0.08
Relative power	2.25	1.83	2.12	2.75	2.25	2.38	2.50	2.33	2.88	2.50	1.75	1.62
Device satisfaction	2.25	2.08	2.21	2.08	1.75	1.83	2.25	2.25	2.50	2.08	1.58	1.54
Perceived productivity	3.62	3.62	3.74	3.53	3.62	3.25	3.59	3.72	3.65	3.56	3.56	3.34
Social attraction	3.88	3.92	3.92	3.50	3.50	3.38	3.75	3.67	3.54	3.62	3.75	3.75

of participants received a score of “1” if the nonuser directly referred to the contents of the display and a score of “0” if the nonuser did not. Perceived power was assessed with a single questionnaire item: “How much did the computer put someone in control?”

Device satisfaction was assessed with a two-item questionnaire. The items were “How much do you like using the computer to manage the collaboration?” and “Do you think the computer helped this interaction?” Across the three time periods and two partners, the reliability of the scale ranged from Chronbach’s $\alpha = .897$ to $.633$, with a mean α of $.782$.⁴² Perceived productivity was assessed with a three-item questionnaire. The items were (1) “How satisfied are you with your interaction?” (2) “How satisfied are you with your contribution to the interaction?” and (3) “How well do you think you are accomplishing your task?” The reliability of this scale ranged from $\alpha = .792$ to $.000$, with a mean α of $.571$. Social attraction was assessed with a three-item questionnaire. The items were (1) “How well are you working together?” (2) “How much would you like to work with your partner in the future?” and (3) “How much fun is your interaction?” The reliability of this scale ranged from $\alpha = .810$ to $.540$, with a mean α of $.678$. In all cases, responses to the questionnaires were in the form of Likert ratings ranging from “1” to “5,” with 1 labeled “not at all” and 5 labeled “extremely.”

Results and discussion. The ratings of disruption were analyzed with a logistic regression analysis. In

this analysis, device familiarity and output sharing were categorical predictors and whether nonusers referred to the display was a binary outcome. The remaining data were analyzed with repeated-measures analyses of variance. Familiarity and output sharing were between subjects; two-level factors and time of assessment were a three-level, within-subject factor. The dependent variables were extroversion, agreeableness, power, device satisfaction, perceived productivity, and social attraction. Separate analyses were run on user and nonuser data. The mean responses of these variables are presented in Table 4.

Social attributions—perceived agreeableness. The system design factors influenced the nonusers’ perceptions of the users’ agreeableness. As shown in Figure 11, partners using a familiar device were perceived as more agreeable over time than those using an unfamiliar device. This effect is statistically significant; for the interaction between time and device, $F(2, 26) = 3.58, p < .05$. In addition, as shown in Figure 12, partners using devices with displays that were hard to share were perceived as less agreeable over time than those using devices with easy-to-share displays. This effect is statistically significant; for the interaction between time and output sharing, $F(2, 26) = 5.91, p < .01$. The system design factors did not significantly influence the users’ perceptions of the nonusers’ agreeableness.

Social attributions—perceived extroversion. The system design factors influenced both the users’ and the

Figure 11 Social attributions: Mean nonusers' perceptions of users' agreeableness by device type

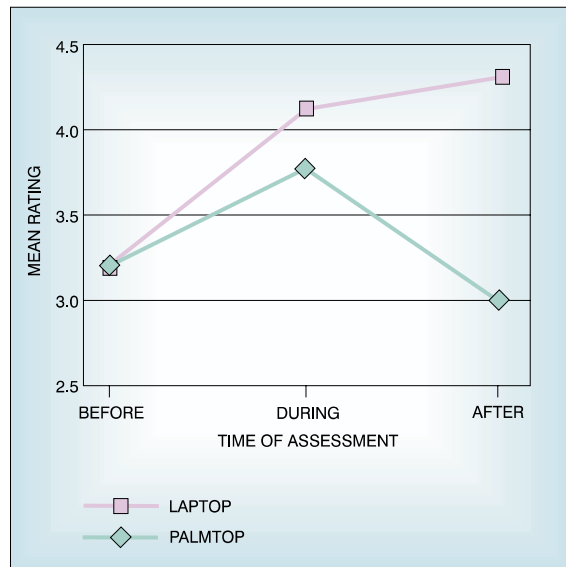


Figure 13 Social attributions: Mean nonusers' perceptions of users' extroversion by device type

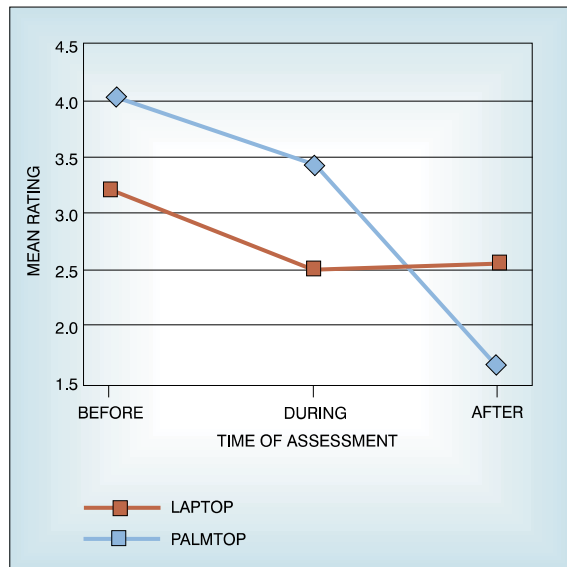


Figure 12 Social attributions: Mean nonusers' perceptions of users' agreeableness by display type

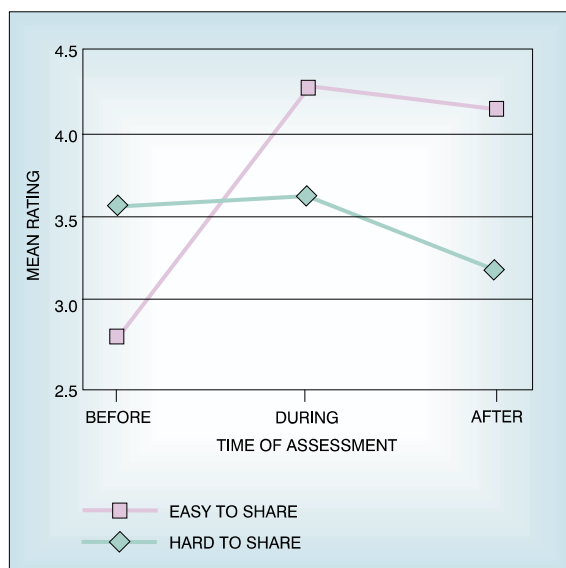
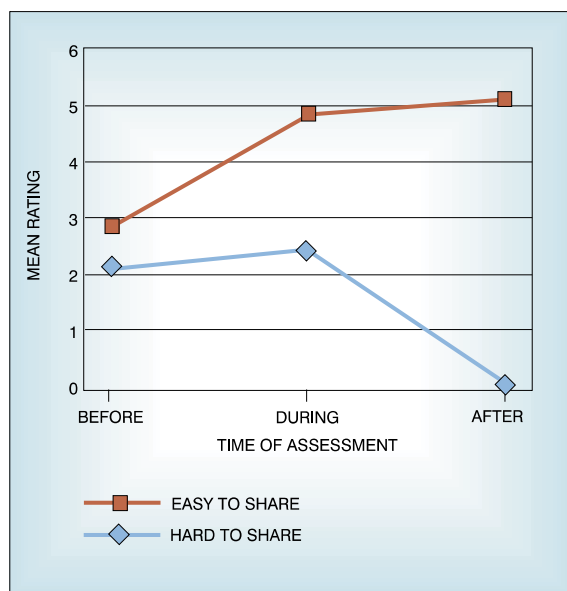


Figure 14 Social attributions: Mean users' perceptions of users' extroversion by display type



nonusers' perceptions of their partner's extroversion. As shown in Figure 13, partners using a familiar de-

vice were perceived as more extroverted over time than those using an unfamiliar device. This effect is

Figure 15 Interaction outcome: Mean users' satisfaction with device by display type

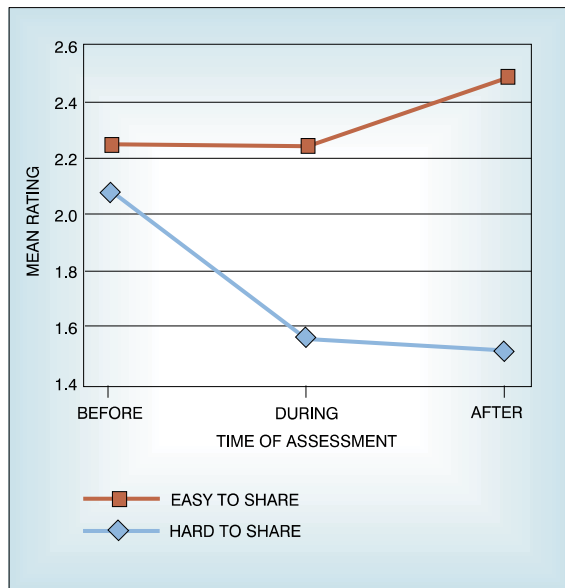
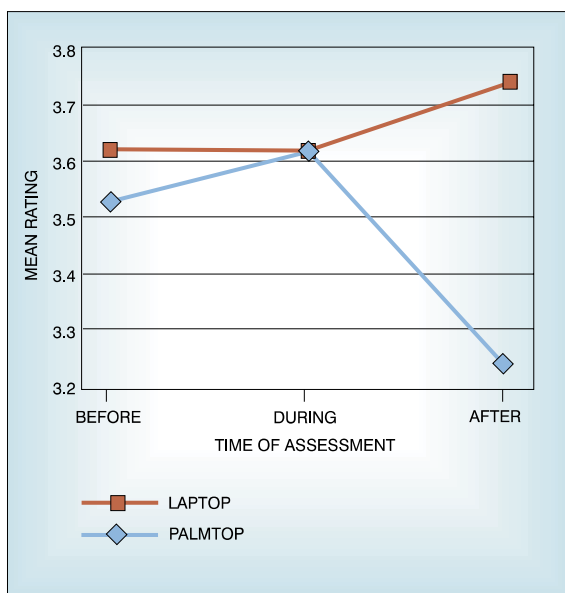


Figure 16 Interaction outcome: Mean users' perceived productivity by device type



statistically significant; for the interaction between time and device, $F(2, 26) = 5.53, p < .01$. The

users' perceptions of the nonusers' extroversion were influenced by the degree of output sharing. As shown in Figure 14, participants who used the devices with easy-to-share displays perceived their partners as more extroverted over time than did participants using hard-to-share displays. This effect is statistically significant; for the interaction between time and output sharing, $F(2, 24) = 3.59, p < .05$.

Human behavior—disruption. Nonusers' behavior was influenced by the degree of output sharing. Participants tended to refer to the display only when the device had an easy-to-share display. For the easy-to-share display, eight out of ten participants referred to the display. For the hard-to-share display, only one out of seven did. This effect is statistically significant; for the logistic regression, $\chi^2(2) = 8.43, p < .05$, and for the categorical predictor output sharing, Wald statistic(1) = 5.46, $p < .05$. The familiarity of the device was not a significant predictor in this analysis.

Human behavior—power. The analyses of power revealed no significant effects; in all cases $F(2, 24) < 3, p$ nonsignificant.

Interaction outcome—device satisfaction. For the users, satisfaction with the device was influenced by the degree of output sharing. As shown in Figure 15, participants who used devices with easy-to-share displays perceived the devices more positively over time than did participants using hard-to-share displays. This effect is statistically significant; for the interaction between time and output sharing, $F(2, 24) = 3.58, p < .05$. Device familiarity did not significantly influence users' satisfaction with the device. Neither system design factor significantly influenced the nonusers' satisfaction with the device.

Interaction outcome—perceived productivity. Users' perceptions of their productivity were influenced by the familiarity of device. As shown in Figure 16, participants who used familiar devices perceived the interactions as being more productive over time than did those who used unfamiliar devices. This effect is statistically significant; for the interaction between time and device, $F(2, 24) = 3.66, p < .05$. Output sharing did not significantly influence the users' perceived productivity. Neither system design factor significantly influenced the nonusers' perceived productivity.

Interaction outcome—social attraction. For the nonusers, the social attractiveness of their partners was

influenced by both the familiarity of device and the degree of output sharing. As shown in Figure 17, partners using familiar devices became more socially attractive over time than partners using unfamiliar devices. This effect is marginally significant; for the interaction between time and device, $F(2, 24) = 2.84, p < .10$. Similarly, as shown in Figure 18, partners using easy-to-share displays became more socially attractive over time than partners using hard-to-share displays. This effect is marginally significant; for the interaction between time and output sharing, $F(2, 24) = 3.38, p < .10$. The system design factors did not significantly influence the users' social attraction to the nonusers.

General discussion

What are the social implications of pervasive computing? In two laboratory studies, we investigated how system design factors might affect the quality of social relationships.

Summary of findings. In our first study, we found evidence that experienced computer users typically expect technology to have a negative impact on social interactions. Even within a highly technical community, most users believe that computer use decreases social activity. Specific system design factors may be mentally associated with negative social interaction outcomes. Of the four devices tested, the less familiar devices tended to elicit more negative expectations than did the more familiar devices. In particular, our participants had more positive impressions of a partner with no computing device than they did of partners with any of the four devices tested. Individuals have expectations about technology's impact on their social lives, and it seems these expectations color their perceptions of targets who use pervasive devices.

In our analyses of the participants' mental interassociations, we discovered that system design factors tend not to be directly associated with interaction outcomes. Instead, design factors may be associated with particular human behaviors and social attributions, and these behaviors and attributions in turn may be associated with interaction outcomes. Psychological identification may be an important step in this process. When partners use devices that perceivers are not inclined to use, they may separate themselves from their partner. The perceiver may see the partner as belonging less to "us" and more to "them." In our study, we found significant positive relationships between identification and the ac-

Figure 17 Interaction outcome: Mean nonusers' social attraction to users' by device type

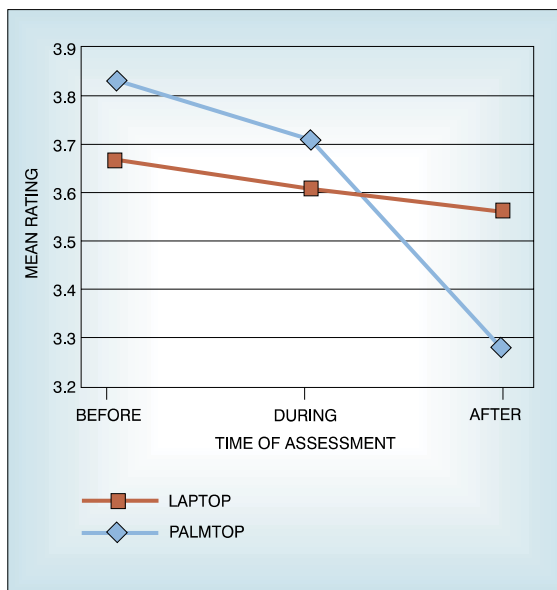
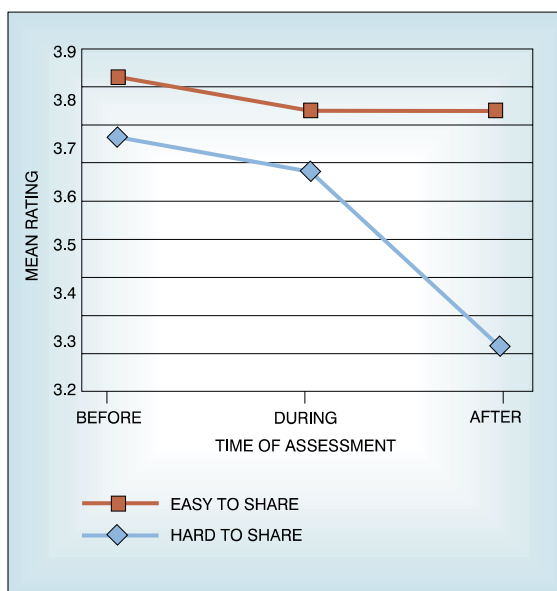


Figure 18 Interaction outcome: Mean nonusers' social attraction to users' by display type



cessibility of a device, its support for shared input and output, and its relevance to a social interaction.

We found significant negative relationships between identification and the degree to which a device disrupts interactions, distracts its user, and appears unappealing. When identification was high, participants tended to be socially attracted to the targets.

In our second study, we found evidence that system design factors can influence the outcome of a social interaction. Changes in a device can make a person using it appear more or less agreeable, extroverted, and socially attractive. These changes can also change the interaction, making it seem more productive, making the device seem more satisfying, and making the nonuser seem more extroverted. These changes occurred even though the experimental manipulations were relatively minor. We manipulated whether the display was relatively easy to share and whether the device was relatively familiar. All the participants, however, had some familiarity with both kinds of devices. Also, even in the conditions with the hard-to-share displays, the users could have shared them. As it happened, however, almost none of the nonusers in the hard-to-share conditions viewed the display at all, and nearly all of the nonusers in the easy-to-share conditions made reference to the display. Relatively subtle design factors can have powerful behavioral consequences.

Comparisons to social interface research. These results can be compared to the results of social interface research. Social computing emphasizes social behaviors, and our evidence supports the claim echoed by social interface theorists that humans are fundamentally social. In our studies, participants consistently made social attributions, even though the variables manipulated were strictly technological in nature. Another similarity with social interface research concerns the generalizability of the findings. Social interface researchers have claimed that, from a psychological perspective, computers are not special. People are likely to treat them and other technology, like voice response systems, televisions, and automated teller machines, in the same way.⁹ We also suspect that wristwatches, cellular telephones, portable radios, and other devices may have an effect similar to the pervasive computing devices examined in this study.

Our work differs from social interface research in that our focus is on attributions made about humans rather than those made about machines. Given this focus, we have studied different independent and dependent variables. Social interface researchers have proposed three factors (language use, social role, and

contingent behavior) as being especially influential for affecting the social attributions humans make about machines. As such, social interface researchers typically manipulate some aspect of a machine's language use, social role, or contingent behavior. Unlike the social interface factors, our theoretical factors are inspired by interpersonal psychology.²⁸ As a result, the independent variables that we have manipulated, such as familiarity of the device and the difficulty of sharing the display, are variables that we hypothesized would affect the interpersonal process. We hypothesized that these design variables would be important based on our observations of persons using pervasive computers. Although the present studies provide empirical evidence of the importance of many of these variables, future research is needed to determine how important they are relative to other variables.

Our work also differs from social interface research in terms of the dependent variables studied. Whereas social interface research has studied the effect of design factors on the perceived personality of a device,⁸ in the present studies we have studied the effect of design factors on the perceived personality of a user. We have shifted the focus from relationships with machines to relationships with individuals. Supporting individuals' social behaviors in interactions with machines is clearly important. Ultimately, however, we believe that humans prefer to have social relationships with humans rather than with machines. Our goal is to support relationships among humans in a world increasingly crowded by pervasive computers.

Theoretical implications. Our studies indicate that pervasive computers may unexpectedly inhibit rather than facilitate social interaction. Unfamiliar devices may trigger negative stereotypes that are strong enough to overwhelm other information that a person has about a partner. Devices that are hard to share may make their users seem disagreeable and withdrawn.

These explanations, however, are not the only ones possible for our results. In laboratory research, there is often a trade-off between experimental control and ecological validity. By increasing experimental control, researchers are better able to rule out some possible alternative explanations because they have manipulated the factors of interest rather than potentially confounding the factors. By increasing ecological validity, researchers are better able to reduce uncertainty about subjects' behavior outside of

the laboratory. In our case, we could have increased our experimental control by building customized systems that differed along the specific factors that we manipulated and were identical in all other respects. Such a study, however, would be a test of experimental systems rather than a test of the mobile devices in the market today. Instead we opted for more ecological validity by using systems that are currently available.

As a result, our experimental conditions differed along more dimensions than those that we have labeled. The output sharing factor, for example, is confounded with input sharing, interpersonal proximity, and ease of eye contact. Familiarity is confounded with a number of design differences, including display size, input technology, and computing power. It may be that these confounding factors, and not the factors we have labeled, are driving the results we have seen.

Nevertheless, we maintain that familiarity and output sharing are reasonable explanations for the results. In Study 1, we found significant evidence that responses to the four devices tended to progress in the same manner as our *a priori* ordering based on familiarity. In Study 2, we found that output sharing affected whether or not the nonuser actually referred to the display. Given the pattern of evidence, we suggest that the confounding factors may be important in addition to, rather than instead of, the factors of output sharing and familiarity.

The focus on familiarity raises the issue of whether all new devices will have a negative social impact. We suspect that new devices may avoid some of the negative impact if they take on seemingly familiar forms. Computers that resemble leather portfolios, watches, and badges may be more successful than those with no familiar form characteristics. Similarly, certain kinds of human-machine interactions may seem more familiar than others. For example, pen and voice input may seem more familiar than keyboard input. Although pen and voice are relatively new ways of interacting with a computer, they are very familiar ways of interacting with information in general. It may be that novel devices with familiar forms, because they seem similar to familiar devices, give potential users confidence that the novel device can be used in a similar way. Moreover, they may identify with users of the novel device because they can draw on analogous experiences; they may see others' use of a novel device as similar to their own use of a familiar device.

Regardless of whether it is familiarity and output sharing, as such, that affect social interactions, the evidence indicates that devices can differ in their effect. The evidence also indicates that this effect is more than mere fleeting first impressions. Although longitudinal research is needed to assess the long-term effect of these factors, the effects grow stronger during an interaction, not weaker. Interpersonal interactions are complicated systems, and the factors studied here represent a small fraction of all the factors that determine the outcome of a particular social exchange. These factors include the partners' actual personality, their role, their goals, and the task context, among many others. In light of all these factors, it is perhaps surprising that small differences in the characteristics of a computing device could have such significant social implications.

We believe that these findings are consistent with a phenomenon called the fundamental attribution error.²⁹ This error refers to the consistent bias toward attributing personal behaviors to internal, rather than situational, causes. In our studies, participants apparently failed to discount adequately for the influence of the device. Instead, they made inferences about the person. This was the case even though the device was clearly given to the user by an experimenter, suggesting that the user did not choose the device or have any control over its design. Even when a user is not responsible for the device, it communicates a social statement about its user.

In these and other ways, computers are likely to disrupt social interactions. Although we would like pervasive computers to avoid being socially disruptive, what we really want is that they be a positive force in social interactions. Designers are only just beginning to envision social computing. If being sensitive to the need for mobility means transforming desktop computers into "wearables," then perhaps being sensitive to the need for collaboration means transforming pervasive computers into "sociables."

Social computing checklist

In order to encourage designers to envision social computing, we offer the "social computing checklist." This checklist is for devices that are designed to be used in the presence of other persons. These are the factors that we expect will have an effect on interaction outcomes, such as device satisfaction, productivity, and social attraction. Although the last three items were not examined in the present studies, we

believe that they may be important and therefore have included them for the sake of completeness.

1. Accessibility. Do nonusers believe that they could use the device easily, and do they understand easily how it works?
2. Familiarity. Is the form of the device one that is familiar and appropriate for the context of its use?
3. Input sharing. Does the device allow nonusers to input information easily and naturally?
4. Output sharing. Does the device allow nonusers to perceive easily and understand output?
5. Relevance. Does the device appear to nonusers to be useful to the user and to the nonuser?
6. Appeal. Is the device something that the user is comfortable being seen using, and do nonusers find the device, and use of the device, attractive?
7. Disruption. Does the device disrupt individuals' natural social behaviors, such as referring to shared information while interacting?
8. Perceiver distraction. Does using the device create noise or otherwise create a distraction for nonusers?
9. Power. To what extent does use of the device put one person more "in charge" than another person, and to what extent does using the device communicate a difference in status?
10. User distraction. Does the device place a high cognitive load on the user during use or otherwise create a distraction?
11. Identification. Does the device appear to include or exclude the user from certain communities, and do nonusers see themselves as persons who would use the device?
12. Pervasiveness. Is the device mobile or otherwise convenient to use in social settings?
13. Communication. Does the device make communication among persons easy, especially the sharing of important social information such as appointments and contact information?
14. Social application. Does the device support rich social interactions, such as through interest matching, meeting facilitation, or social networking?

Conclusion

Pervasive computers may have an important effect on individuals' social lives. Our research suggests that devices can affect the mechanisms that determine when interactions are satisfying and productive. Because our current devices have not been designed

to support social interactions, they can make users appear socially unattractive. The implication of this research is that widespread use of pervasive computers can change the ways in which we see our partners and ourselves and the ways in which we live our social lives.

Nevertheless, we doubt that our inevitable future is to become a machinelike collective society. How devices are used is not determined by their creators alone. Individuals influence how devices are used, and humans can be tenaciously social creatures. Humans have used technologies such as telephony and e-mail primarily for social purposes even though creators of the technologies did not envision a social application. Given the importance of social relationships in our lives, we may adopt only those devices that support, rather than inhibit such relationships.

If pervasive computers are to be successful, they need to support human social lives. This support may involve targeting the needs of a specific community, intentionally creating social actors, or providing systems that help individuals collaborate at a distance or in person. Designers of winning pervasive computing solutions will understand the mechanisms behind interpersonal satisfaction and collaborative productivity. They will avoid the pitfalls that disrupt successful interactions. By designing for social computing applications, they will move pervasive computing away from social hindrance toward social necessity.

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